Present Transfer Line Status

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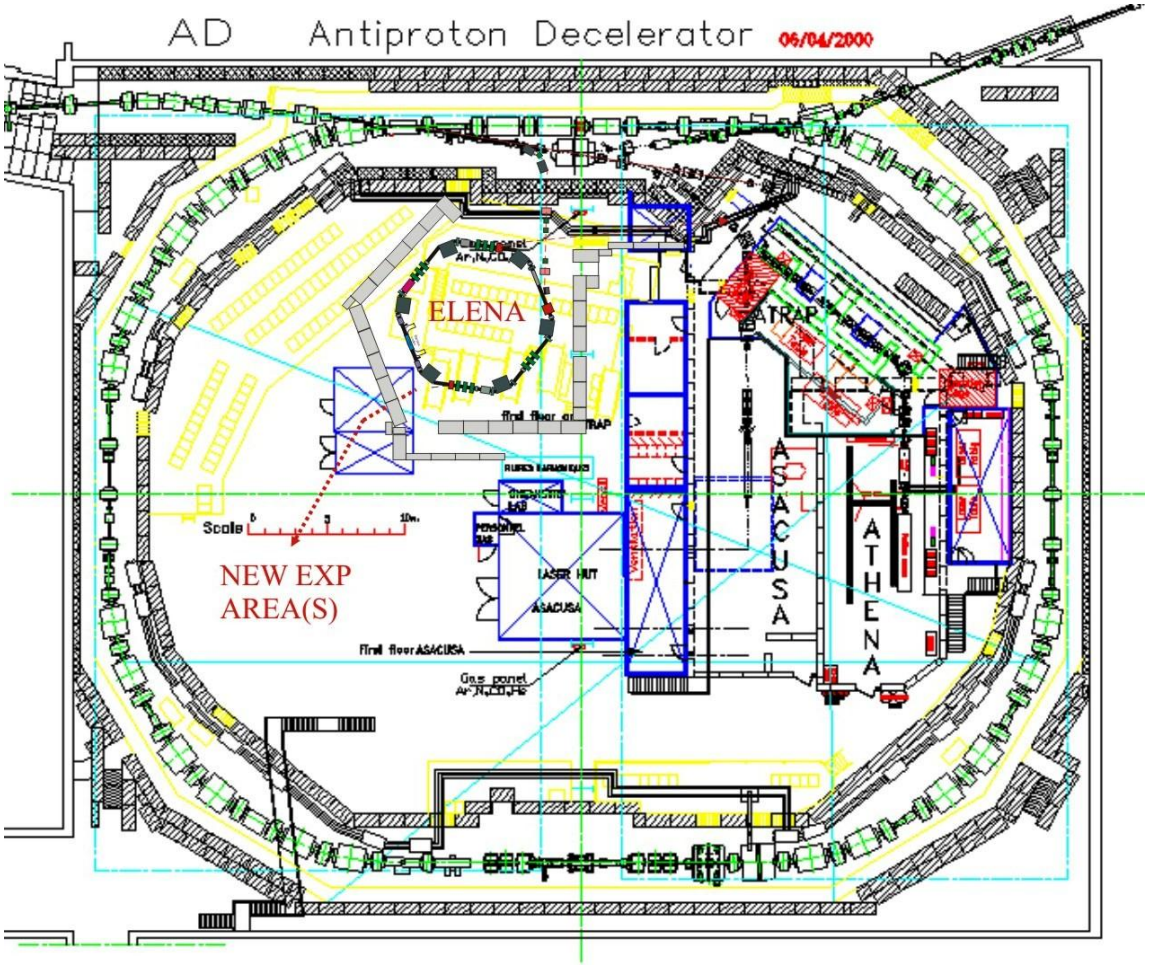
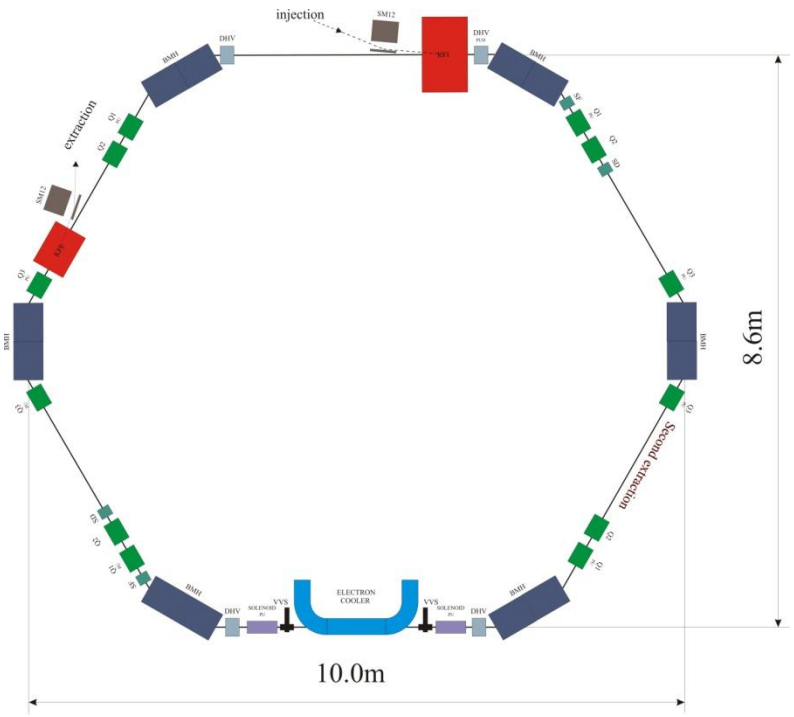
BE/OP

ELENA layout in AD Hall



ELENA ring configuration

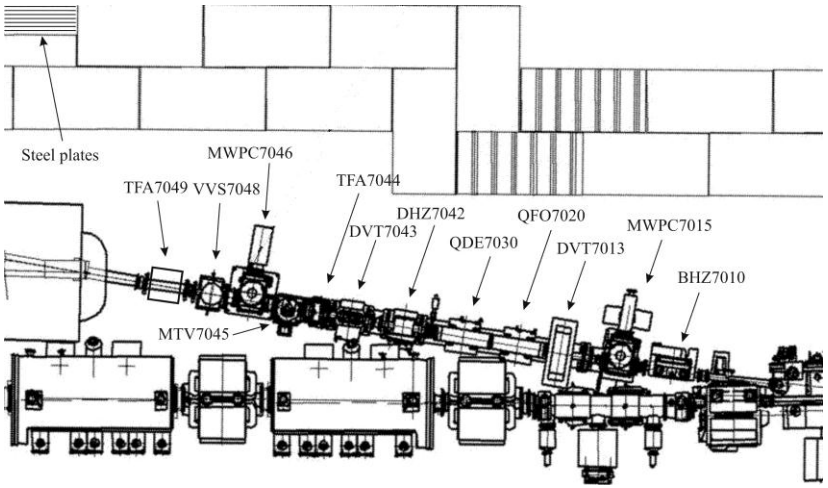
- Two straight sections without quadrupoles, for injection and for electron cooling
- Four straight sections, each includes 3 quadrupoles for beam focusing
- Injection and extraction made in a different section to facilitate beam transfer from AD to ELENA and from ELENA to experimental area
- Second extraction is foreseen for future experiments (Gbar experiment is approved by SPSC)



ELENA beam injection parameters

Momentum, MeV/c	100
Energy, MeV	5.3
Intensity of injected beam	~3×10^7
Number of injected bunches	1
Emittances (h/v), π·mm·mrad, [95%]	<15
Δp/p, [95%]	$2 \cdot 10^{-4}$
Bunch length, ns	<500

Beam transfer from AD to ELENA

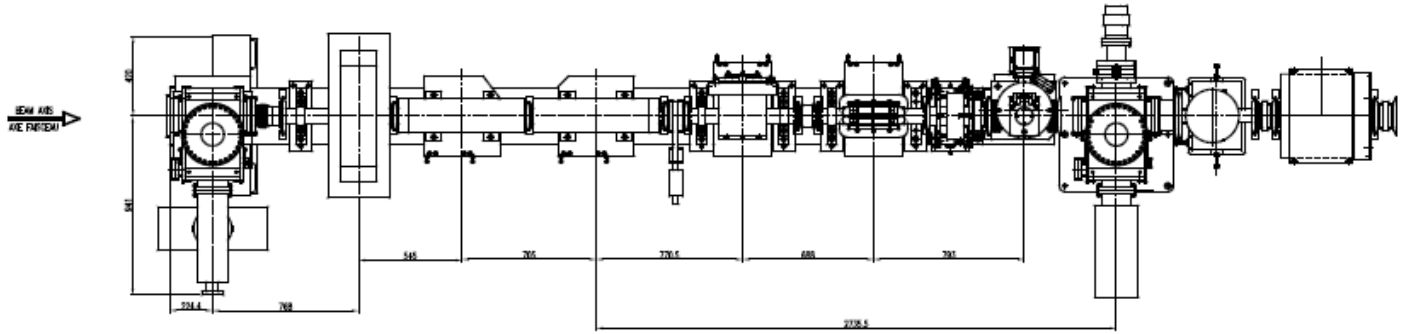


What should we modify in AD ejection line (7000 line):

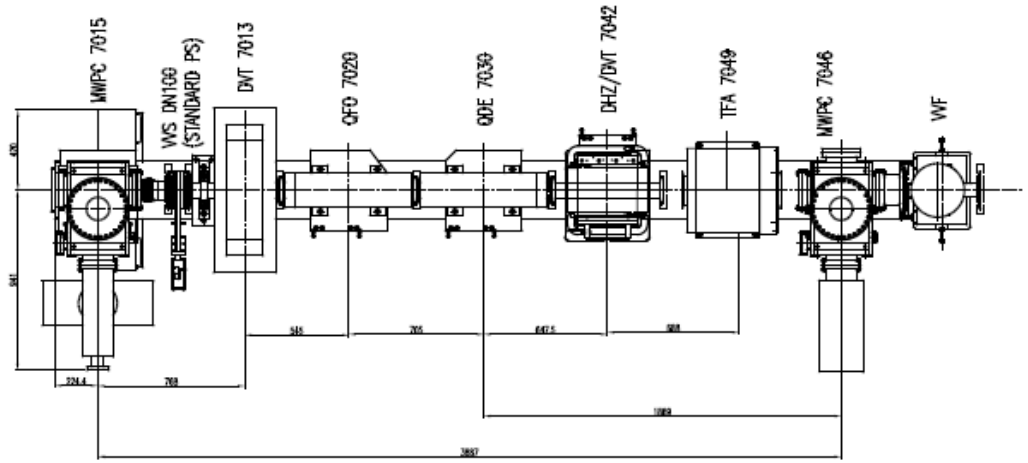
- place sector valve VVS32 between MWPC7015 and DVT7013 (possible)
- move dipole correctors 7042 and 7043 upstream (to be confirmed by vacuum specialists), build new combined corrector (proposed by T. Eriksson)
- remove proton transformer TFA7044 and MTV7045 (possible)
- To place current transformer TFA7049 before MWPC7046 (possible)
- To make small modification in vacuum equipment in this area (to be confirmed by vacuum specialists)

Modification in AD 7000 line

Today's layout

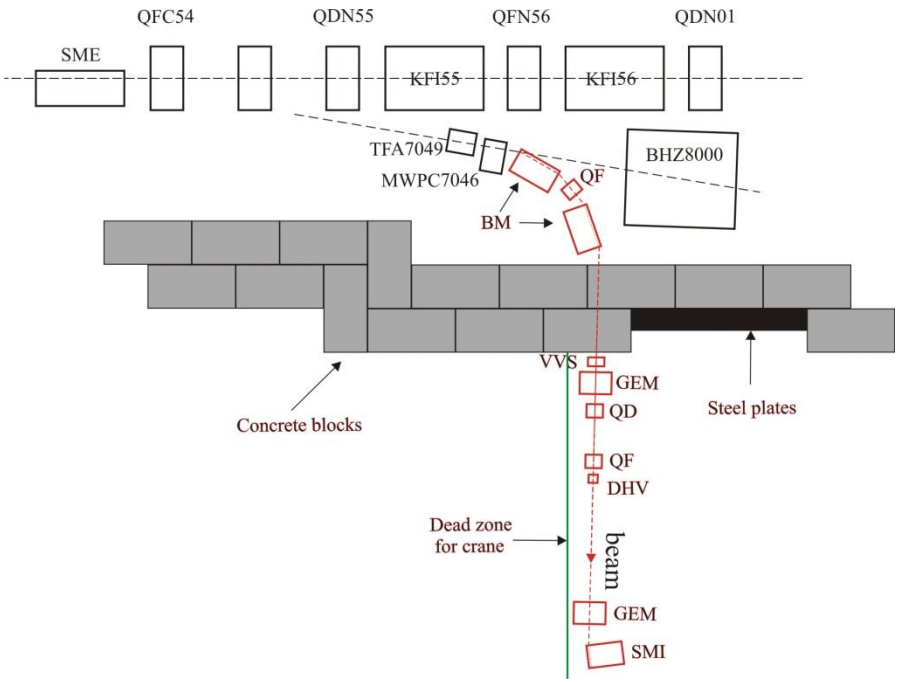


Proposed layout

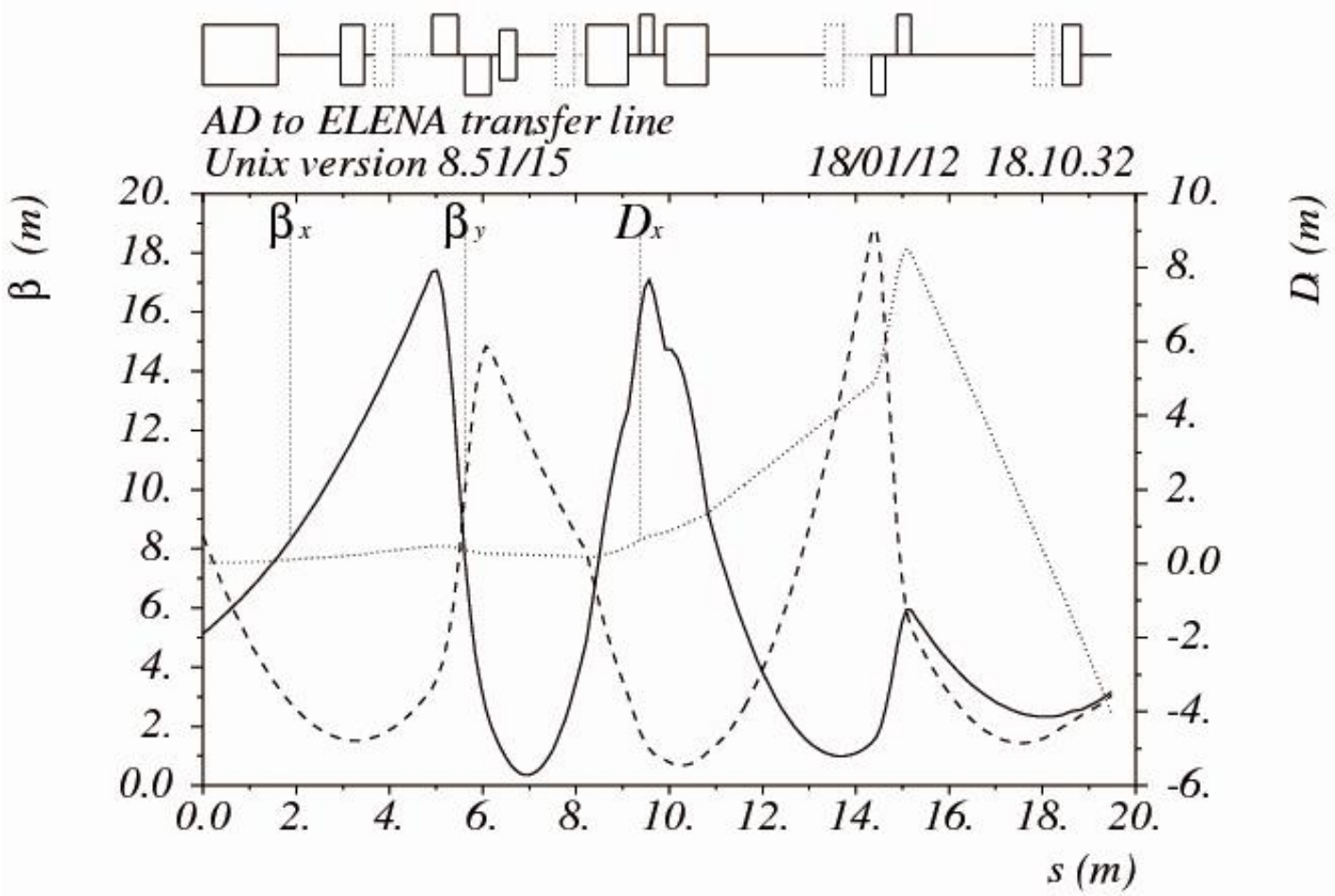


AD to ELENA transfer line

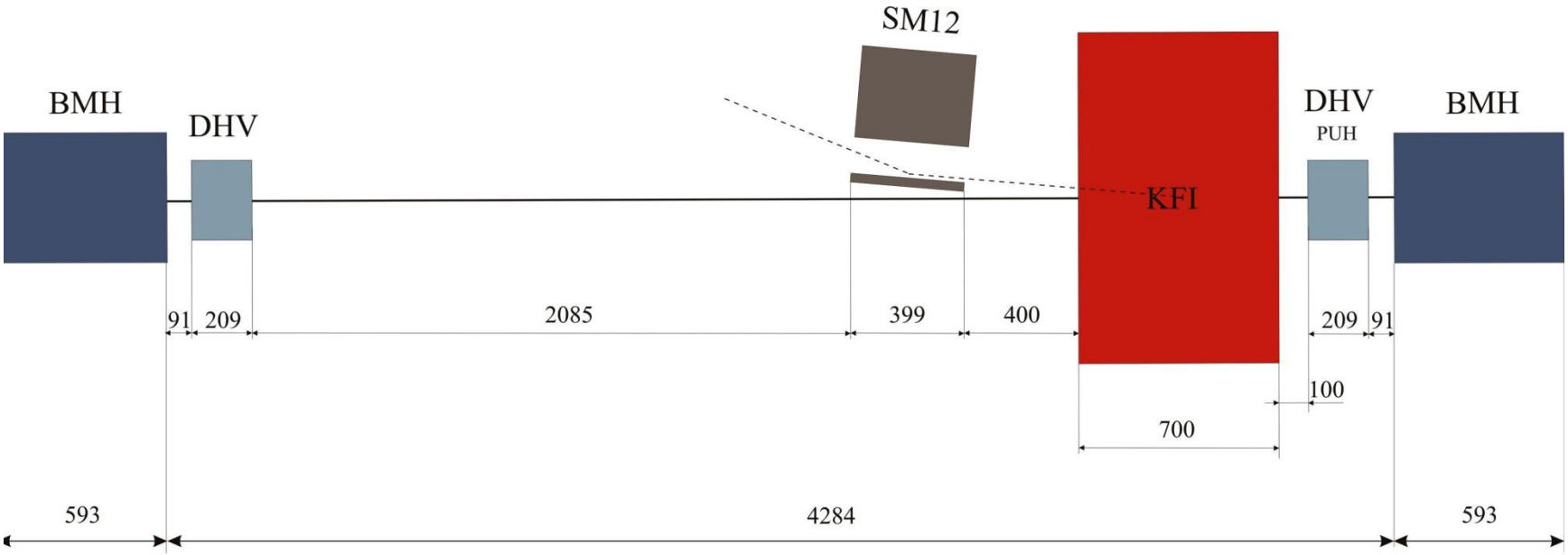
- To make 82˚ bend, two magnets will be placed upstream to the shielding of AD Hall
- 5 or 6 quads used for matching of the Twiss functions. Matching of dispersion is not possible, a small mismatch and the horizontal emittance blow up expected. Small momentum spread in AD beam required, no bunch rotation in AD, longer flat part for injection kicker
- The line layout and length limited strongly by layout (unfortunately)
- Special care should be given to a crossing of injection and extraction lines



AD to ELENA transfer line optics



Injection into ELENA



Parameters of injection septum

Momentum, MeV/c	100
Deflection angle, mrad	303
Required $\int B \cdot dl$, T·m	0.101
Gap height, mm	74
Gap width between conductors, mm	135
Septum conductor thickness, mm	22.8
Magnetic length, mm	300
Magnet length (physical), mm	400
Good field region ($\pm 5 \cdot 10^{-3}$), mm	
Current (DC), A	991

Parameters of injection kicker

momentum, MeV/c	100
Revolution time, ns	955
Rise time, ns	300
Fall time, ns	300
Flat part, ns	~600
Required angle, mrad	84
Required $\int$Bdl, G·m	280
Maximal $\int$Bdl, G·m	313
Good field region ($\pm 5 \cdot 10^{-3}$), mm	70x40
Magnetic length, mm	432
Tank length, mm	700

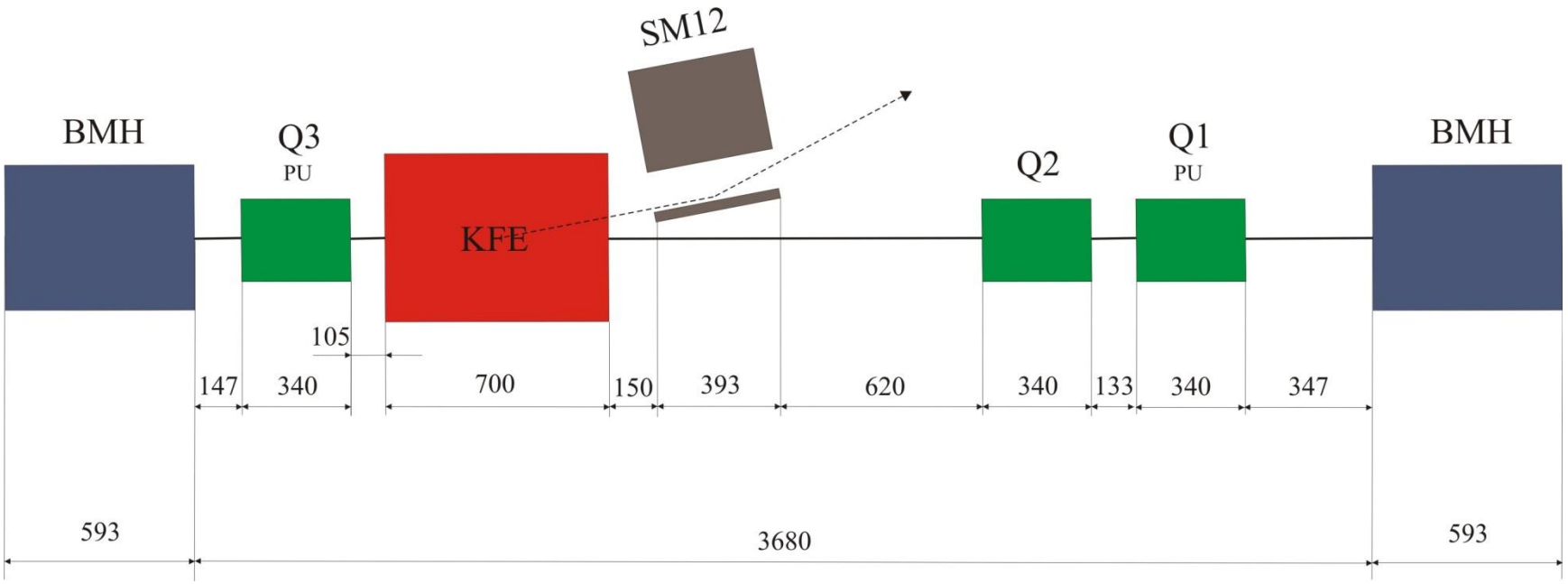
Next steps

- Define modified 7000 line layout together with survey, vacuum and design office people
- Define preliminary layout of ELENA ring in AD Hall
- Define bending magnet parameters together with magnet group people
- Define vacuum equipment in AD to ELENA transfer line
- Make matching of Twiss functions between AD and ELENA
- Make estimation of possible beam blow up during injection due to (dispersion) mismatch
- Make estimation of possible beam blow up during injection due to injection kicker/septum errors

ELENA beam extraction parameters

Momentum range, MeV/c	13.7
Energy range, keV	100
Intensity of ejected beam	1.8×10^{7}
Number of extracted bunches	1 to 4
Emittances (h/v), π·mm·mrad, [95%]	4 / 4
Δp/p after cooling, [95%]	10^{-4}
Bunch length at extraction, m / ns	1.3 / 300

Extraction from ELENA in a short straight section



Extraction from ELENA in a short straight section: summary

- Suitable for various optics
- Short space, big angles in deflecting elements required
- Strong kicker needed (δ_k=190 mrad) , module of former AA injection kicker may be used. The beam deviation inside the kicker is 38.8mm, the beam size of ejected beam is

$$\sigma_x = [\varepsilon_x \beta_x + (\Delta p / p)^2]^{1/2} = [8 \cdot 5 + (3 \cdot 1)^2]^{1/2} = 7\ mm$$

and the space for beam is 38.8+2·(7+3)=58.8 mm (3 mm added for trajectory error), which fits good field region. When optics will be finalized, this value should be revised.

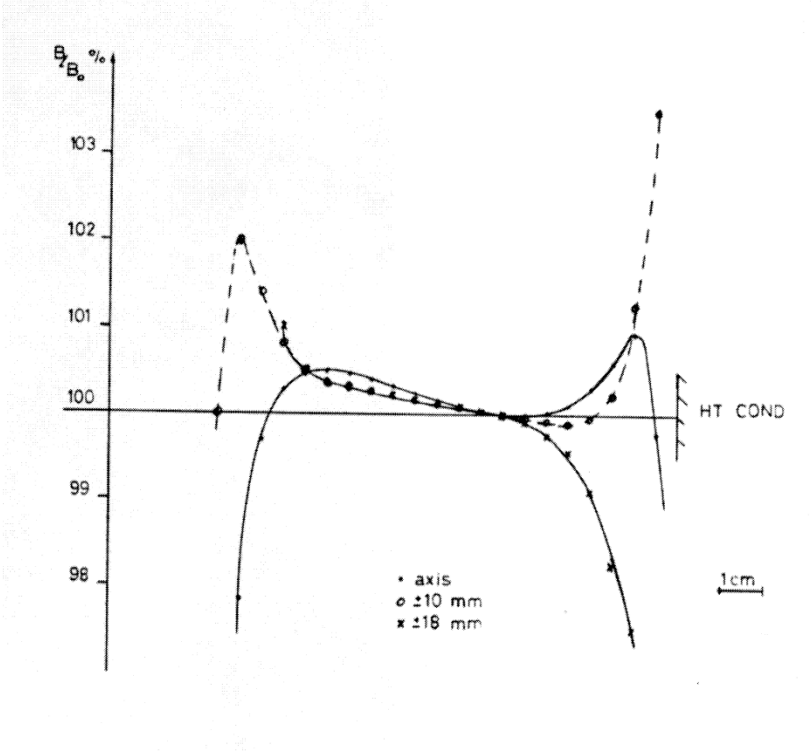
- Magnetic septum SMH12 may be used (HxV=135x74 mm), δ_s=303 mrad -> 60 mm needed for trajectory deviation and 75 mm are available for ejected beam

Some parameters of ejection kicker (PS/BT/Note 87-5)

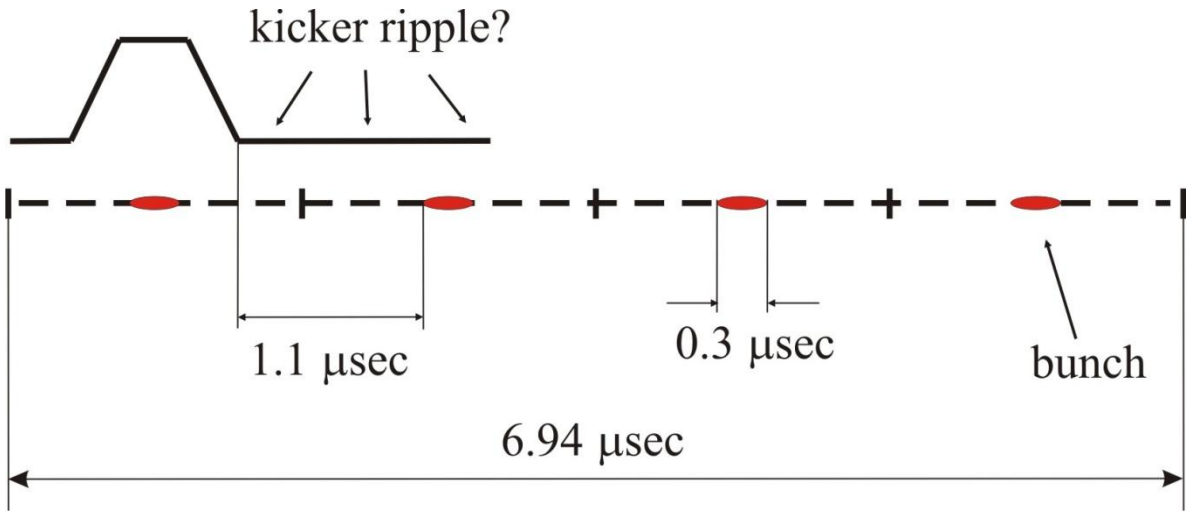
Kicker parameters

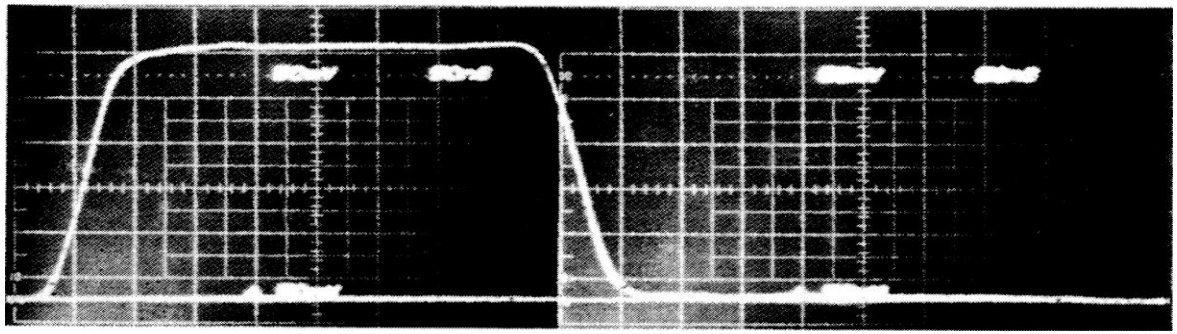
p	MeV/c	13.7
w (w_{eff})	mm	110 (132)
h	mm	45
L_{magn} /L_{tank}	mm	432/700
$\int B \cdot dl$ /$\int B \cdot dl_{max}$	G·m	93/313
$\int B_{rem} \cdot dl$	T·m	$0.75 \cdot 10^{-4}$
Rise time (2-98)%	ns	300
Fall time (98-2)%	ns	300
Flat top length	ns	400

Field uniformity



Effect of the kicker ripple (4 bunches case)





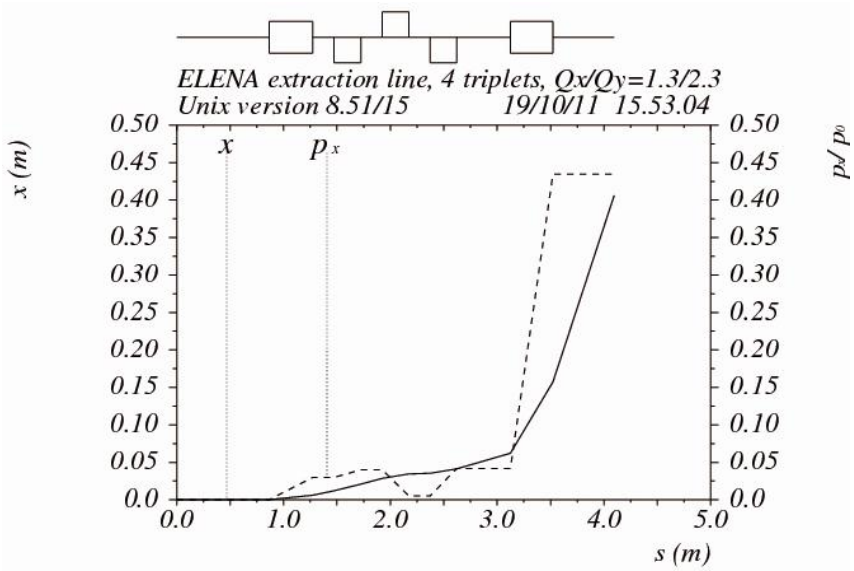
Effect of the kicker remanent field

- Kick applied to circulated bunches is noticeable and has to be compensated

$$\delta = \frac{\int B_{rem} dl}{B\rho} = \frac{0.75 \cdot 10^{-4}}{13.7 \cdot 10^{-3} \cdot 10/3} = 1.6 \cdot 10^{-3}$$

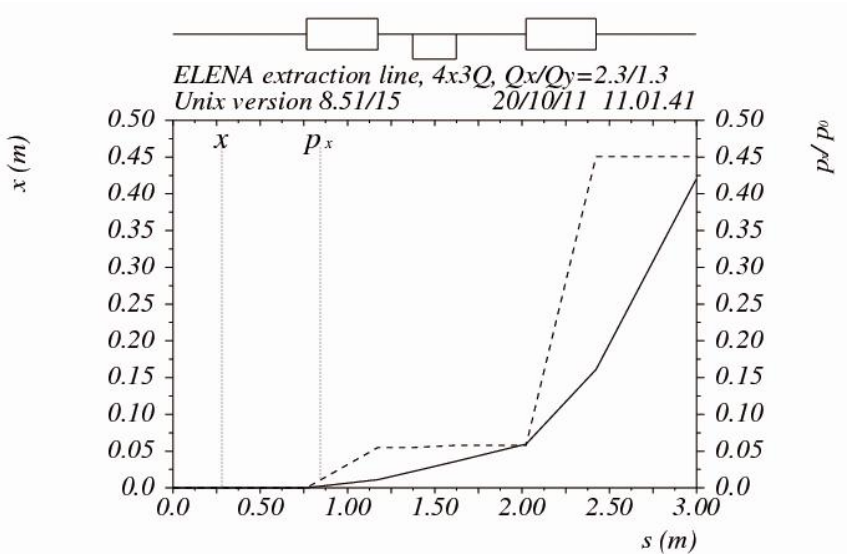
Beam extraction through a triplet

- The best among optics with tunes Q_x=1.3, Q_y=2.3 has been chosen for study, with edge angles of $\pi/9$. For the same edge angle the ejection through triplet is less efficient in case of tunes Q_x=1.45, Q_y=2.45
- Positive: small kicker angle of 30 mrad
- Negative: 32 mm only needed for circulating beam (4σ) with ε_x=50 π mm mrad (ring acceptance), and $2 \cdot$ (50 to 60) mm needed for ejected beam
- Negative: 1 to 3 quadrupoles of special design needed (wider aperture-> bigger length), extra power supplies, 2 extractions in ELENA foreseen-> double problems



Beam extraction through central defocusing quadrupole

- Optics with 3 quads in each of 4 straight section was chosen. The edge angle is $\pi/11$, tunes are $Q_x=2.3$, $Q_y=1.3$
- Modest kick of 55 mrad required, and trajectory deviation at the exit of quadrupole is 36 mm
- About 20 mm required for circulating beam (4σ) with $\varepsilon_x=50\ \pi$ mm mrad (ring acceptance), and $2 \cdot 45$ mm needed for ejected beam
- Negative: one quadrupole of special design with big aperture needed, extra power supply, 2 extractions in ELENA foreseen -> double the problems



Comparison of two extraction schemes with magnetic kicker and septum

Extraction in a short straight section:

- doesn't depends on optics
- needs less space
- Needs strong kicker

Extraction through the quadrupole(s):

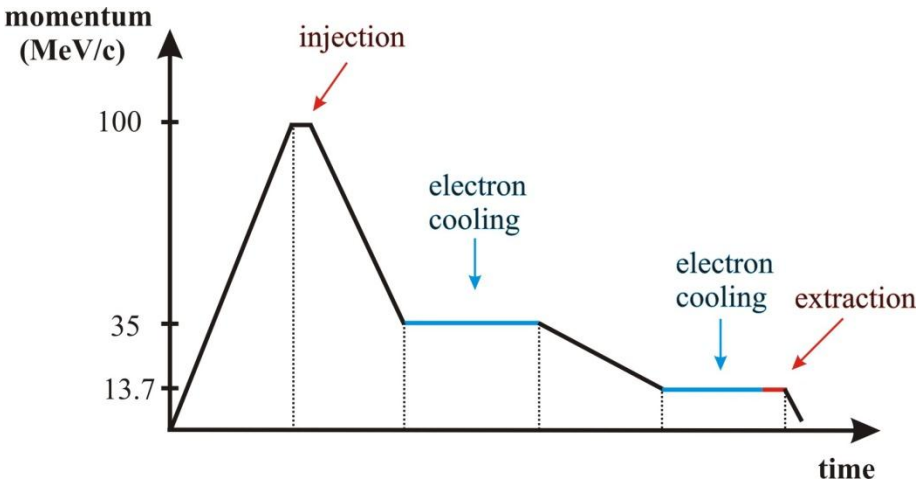
- requires much weaker kicker strength
- Requires much bigger quadrupole aperture and, as a result, bigger length
- Requires special magnet design
- Cost of magnet system increased
- Makes optics set up more complicated

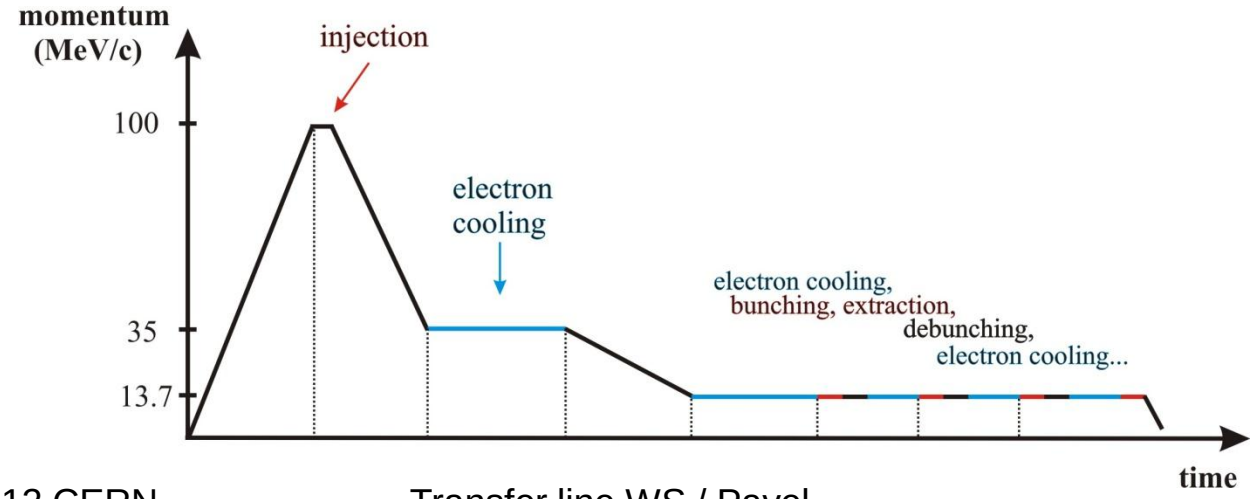
Extraction in a short section with strong kicker is proposed

How we extract from ELENA more than one bunch?

- One can't extract more than 1 bunch during one turn due to limitation on kicker flat part duration (400 nsec) and speed of switching between experiments
- The limiting factor for the next extraction is recharging of kicker capacitor, it takes up to 100 msec.
- Two scenario to continue extraction process: a) beam is keeping bunched until kicker is ready for the next fire, one needs about 100 msec, 200 msec or 300 msec to extract 2, 3 or 4 bunches (synchronization between RF and kicker takes 20 to 30 msec) or b) beam is debunched, cooled again and rebunched after each extraction
- For the first option a) relatively small beam emittance blow up due to residual gas scattering is expected, b) IBS-caused emittance blow up occurs during beam bunching and keeping on extraction plateau
- Could one make fast emittance measurement right before extraction? This is the only way to estimate danger from IBS
- Both options have to be foreseen from the point of view of control system: long beam stay on extraction plateau and debunching/cooling/bunching procedure

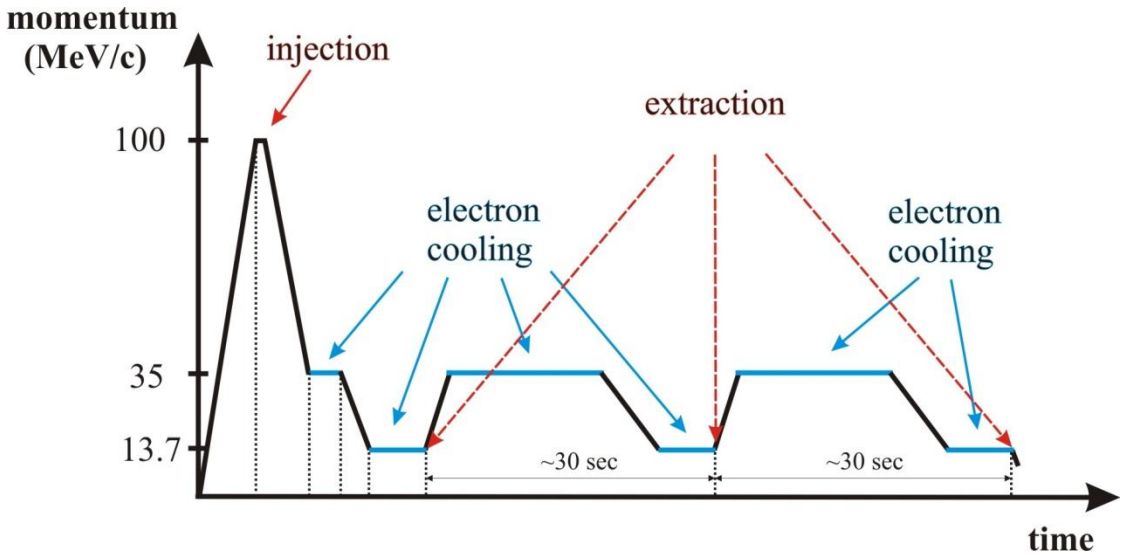
How we extract from ELENA more than one bunch?





We can deliver to one experiment 3 bunches during one AD cycle

- In case one or few of the experiments uses accumulated pbars during long time (i.e.15 min)
- In case one of the experiments has requirements to beam which differs from other requests (i.e. ASACUSA needs shorter bunch length, but accept relatively big emittances)
- In case one need to test machine parallel with physics



Could we make extraction with electrostatic kicker?

Motivation:

- To extract more than one bunch at the time (longer kicker flat part required)?
- Absence of the kicker remanent field

Important:

- How fast could one make switching between experiments with electrostatic bending magnet(s)?
- Do we have other advantages of electrostatic kicker w.r.t. magnetic kicker?

Crossing of injection and extraction beam lines

Special care:

- Choice of the best point to make crossing
- Constraints on equipment location in both lines
- Extra pumping in AD to ELENA transfer line, in a part which is inside of AD Hall

Electrostatic lines

- completely new area for AD/ELENA team…
- at least 5 experiments to be served (ASACUSA, ALPHA, ATRAP, AEGIS. GBAR)
- Several tens of meters total length
- Must be shielded
- Acceptance about 15 pi mm mrad (to be confirmed)
- Focal point with small beam size (about 1 mm) at the end of line
- Flexible system for switching beam between experiments
- Stable parameters of delivered beam

Your experience is welcome!

Thank you for attention!